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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NORDA Technical Note 149	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) JHU/APL Heat Flux Spar Buoy Mooring		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Darrell A. Milburn		8. CONTRACT OR GRANT NUMBER(s) JHU/APL Letter Agreement No. 601557-0
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Ocean Research and Development Activity Code 351 NSTL Station, MS 39529		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Ocean Research and Development Activity Code 351 NSTL Station, MS 39529		12. REPORT DATE August 1982 13. NUMBER OF PAGES 20
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Unlimited		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Buoy Systems Moorings Standard Krypton, Phase I		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The buoy system used to successfully moor the JHU/APL Heat Flux Spar Buoy in Phase I of the Standard Krypton is described. Rationale for component and system selection are also discussed, and selected mooring results are presented.		

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S/N 0102-LF-014-6601

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Superintendent (Code 1424)
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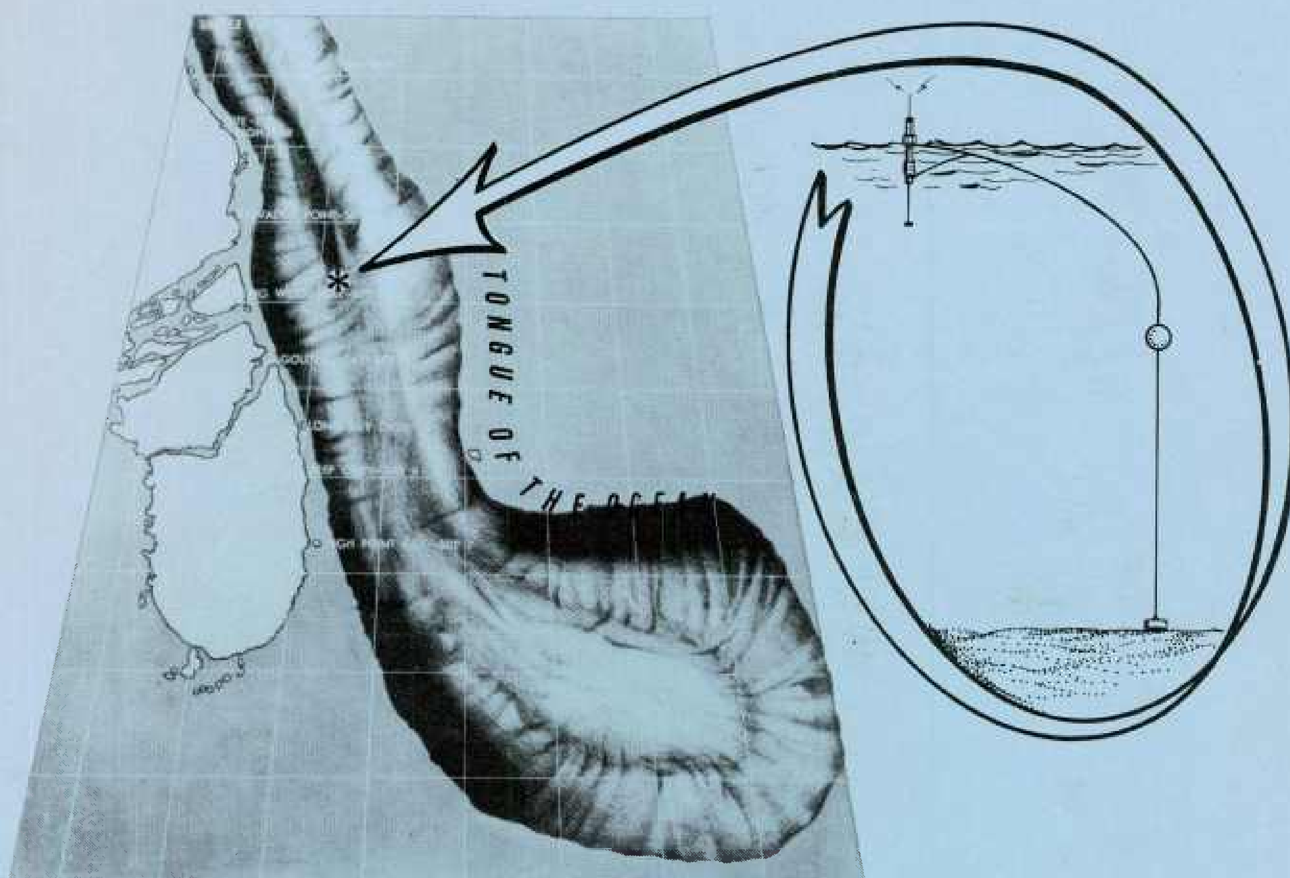
NORDA Technical Note 149

Naval Ocean Research and Development Activity
NSTL Station, Mississippi 39529

NAVAL OCEAN RESEARCH AND DEVELOPMENT ACTIVITY
NORDA
1976

JHU/APL Heat Flux Spar Buoy Mooring



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August 1982

ABSTRACT

The buoy system used to successfully moor the JHU/APL Heat Flux Spar Buoy in Phase I of the Standard Krypton is described. Rationale for component and system selection are also discussed, and selected mooring analysis results are presented.

ACKNOWLEDGEMENTS

Special thanks to Ms. P. Harris who assisted with the mooring analysis, to Messrs. P. Bishop and A. Albrecht who fabricated the mooring, and to the JHU/APL crew aboard the R/V COVE who assisted with the buoy system deployment.

This work was funded by JHU/APL Letter Agreement No. 601557-0.

CONTENTS

ILLUSTRATIONS

JHU/APL HEAT FLUX SPAR BUOY MOORING

I. INTRODUCTION

The Johns Hopkins University Applied Physics Laboratory (JHU/APL) Heat Flux Spar Buoy was recently used to gather environmental data in phase I of the Standard Krypton (Grabowski and Sarabun, 1981). The 17.8 kN (4000 lb), surface-decoupled buoy is shown schematically in Figure 1. Basically, it consists of three slender cylinders, each about 19 ½ m long. And it is equipped with sensors for measuring air temperature and pressure, wind velocity, relative humidity, water temperature, and net short and long wave radiation. Other features of the buoy include: A telemetry system for transmitting the measured data to shore; a sensor battery pack adequate for 8 to 10 days of continuous operation; a damping plate; and, a reserve buoyancy module to provide extra flotation in the event the spar buoy should sink below its desired water line.

In Phase I of the Standard Krypton, the JHU/APL spar buoy was moored to a buoy system in the Tongue of the Ocean, Bahamas. The mooring site, where the water is 1540 m deep, is shown in Figure 2.

This report concerns the buoy system which was designed and fabricated by the Naval Ocean Research and Development Activity (NORDA) for JHU/APL. In particular, it provides a detailed description of the mooring, the rationale for system and component selection, and a brief description of the system's at-sea performance during Phase I of the Standard Krypton.

II. BUOY SYSTEM DESIGN

A. Preliminary Phase

Figure 3 is a conceptual drawing of the mooring selected by NORDA for

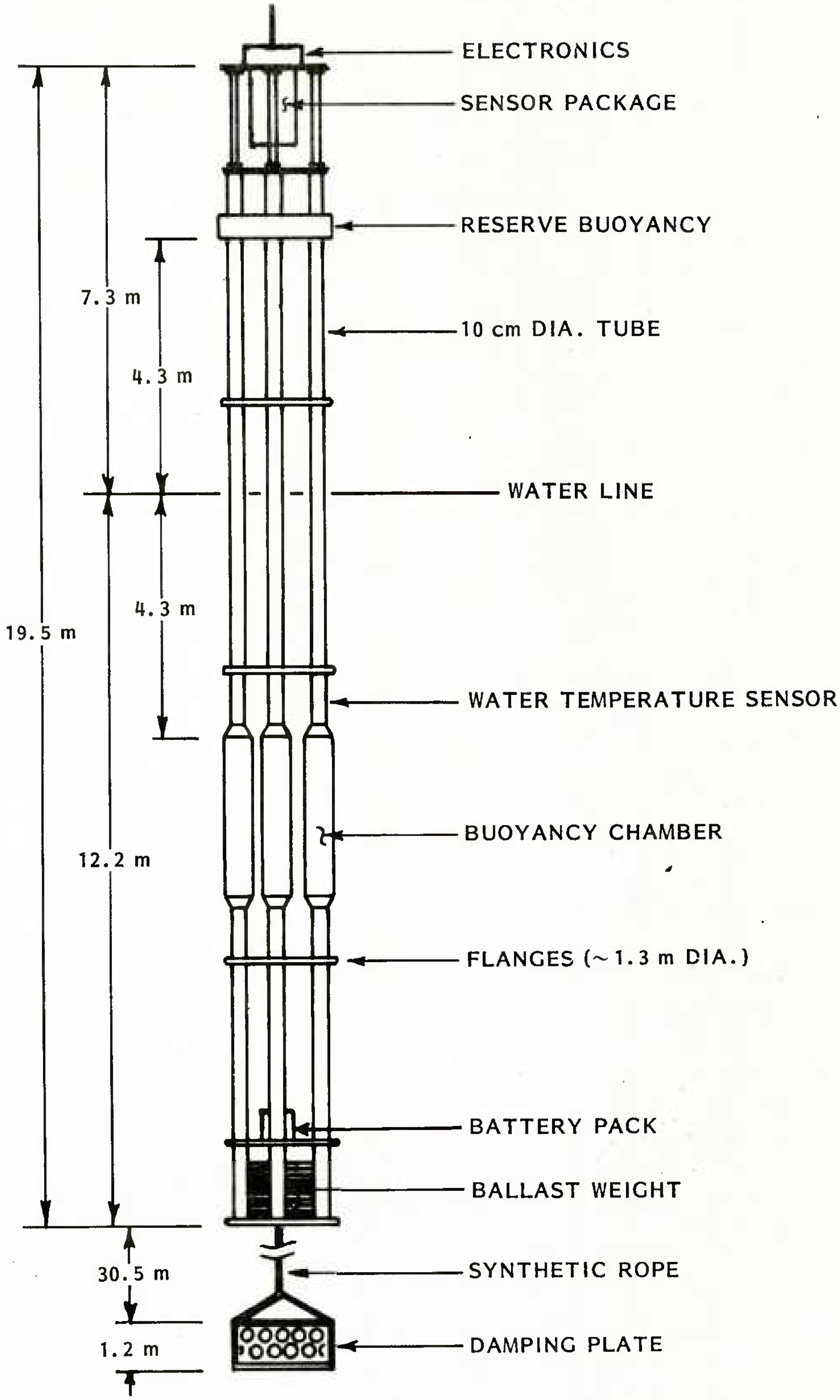


Figure 1. JHU/APL Heat Flux Spar Buoy

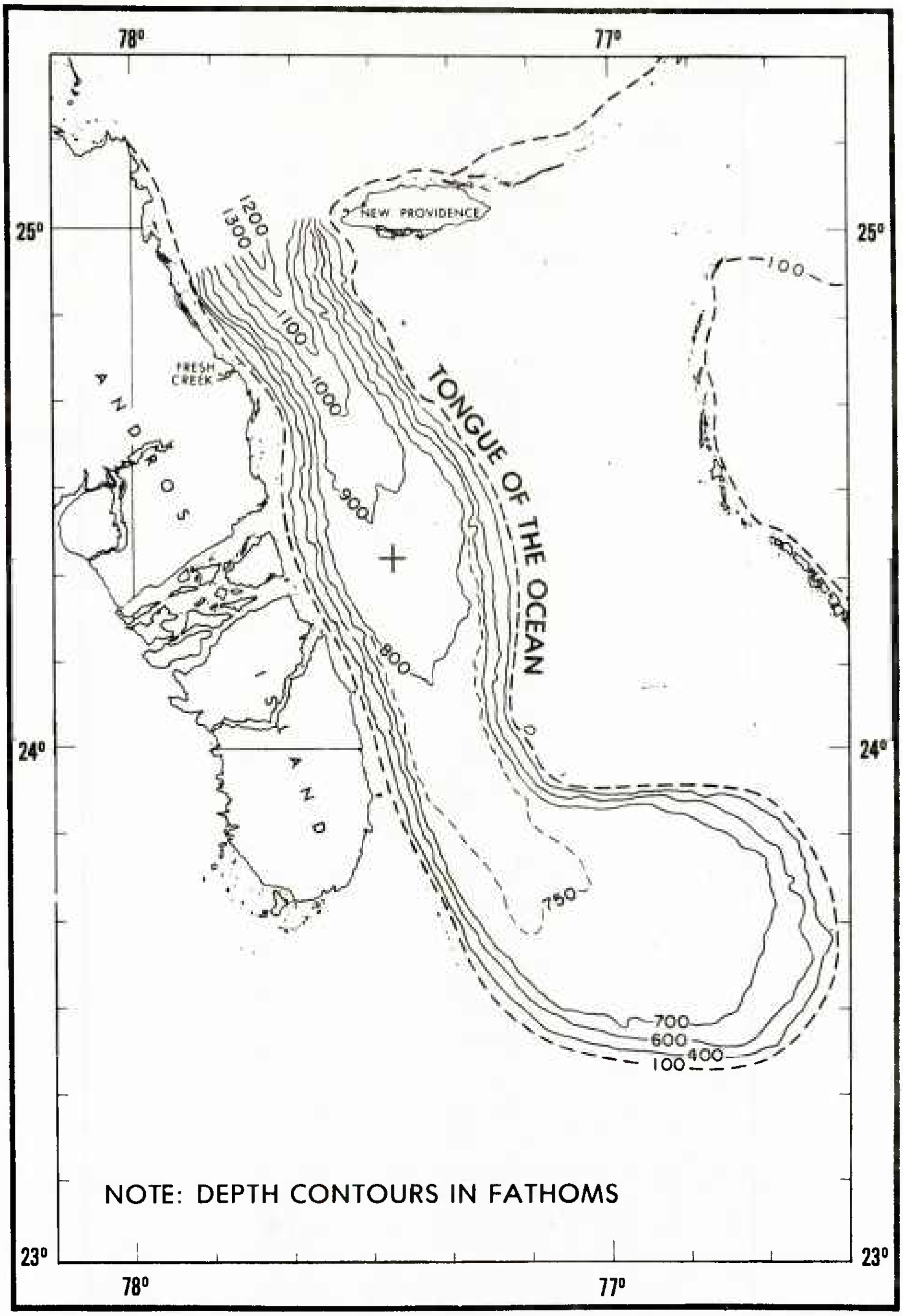


Figure 2. Tongue of the Ocean: Bathymetry. The cross shown between the 800 and 900 fathom contours designates the mooring site.

anchoring the spar buoy. The mooring has one anchor point and, therefore, only one leg. Compared to a multi-leg system, it is less expensive and much easier to deploy. Multi-leg systems, however, have the advantage of reduced watch circle which is caused by slowly changing ocean currents. But watch circle, or station-keeping, was not an important design consideration.

The intent of the Figure 3 design is to suppress, or minimize, the effect of mooring dynamics on the spar buoy. This is accomplished by using a slack, positively buoyant tether line and a subsurface buoy. In this approach the subsurface buoy is the primary flotation unit and is tautly anchored to the bottom with a mooring line. More importantly, it is located below the effects of surface wave action, the dynamic forcing function of concern. Hence only the tether line is effected by surface waves, and these effects should be small since the line is slack. Other alleged advantages of this design include: No large mass (primary buoyancy unit) on the surface to collide with the spar and little, if any, chance of the tether line tangling with other mooring components since it is positively buoyant.

As a next step in the design process, a preliminary design was synthesized using readily available parts. It was then analyzed to examine its steady-state response to forcing caused by ocean currents and system deployment. In the mooring analysis, the following important features were considered: mooring line elasticity, normal and tangential hydrodynamic loading on the lines, forces due to gravity, and drag forces on all attached devices.

By comparing the predicted performance with that which was desired, the design was then finalized. It is shown schematically in Figure 4, and is described in the next section.

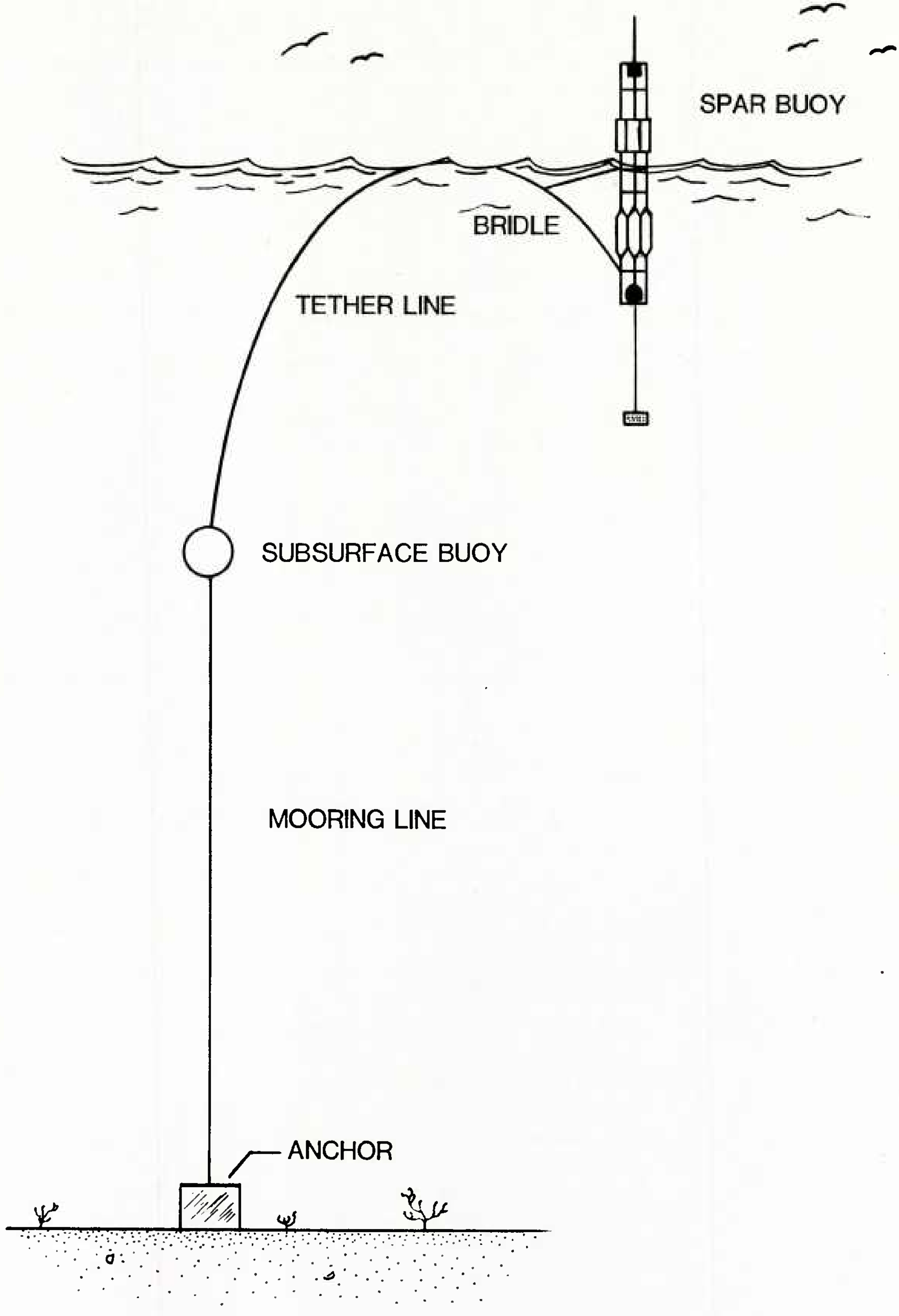


Figure 3. Mooring design concept

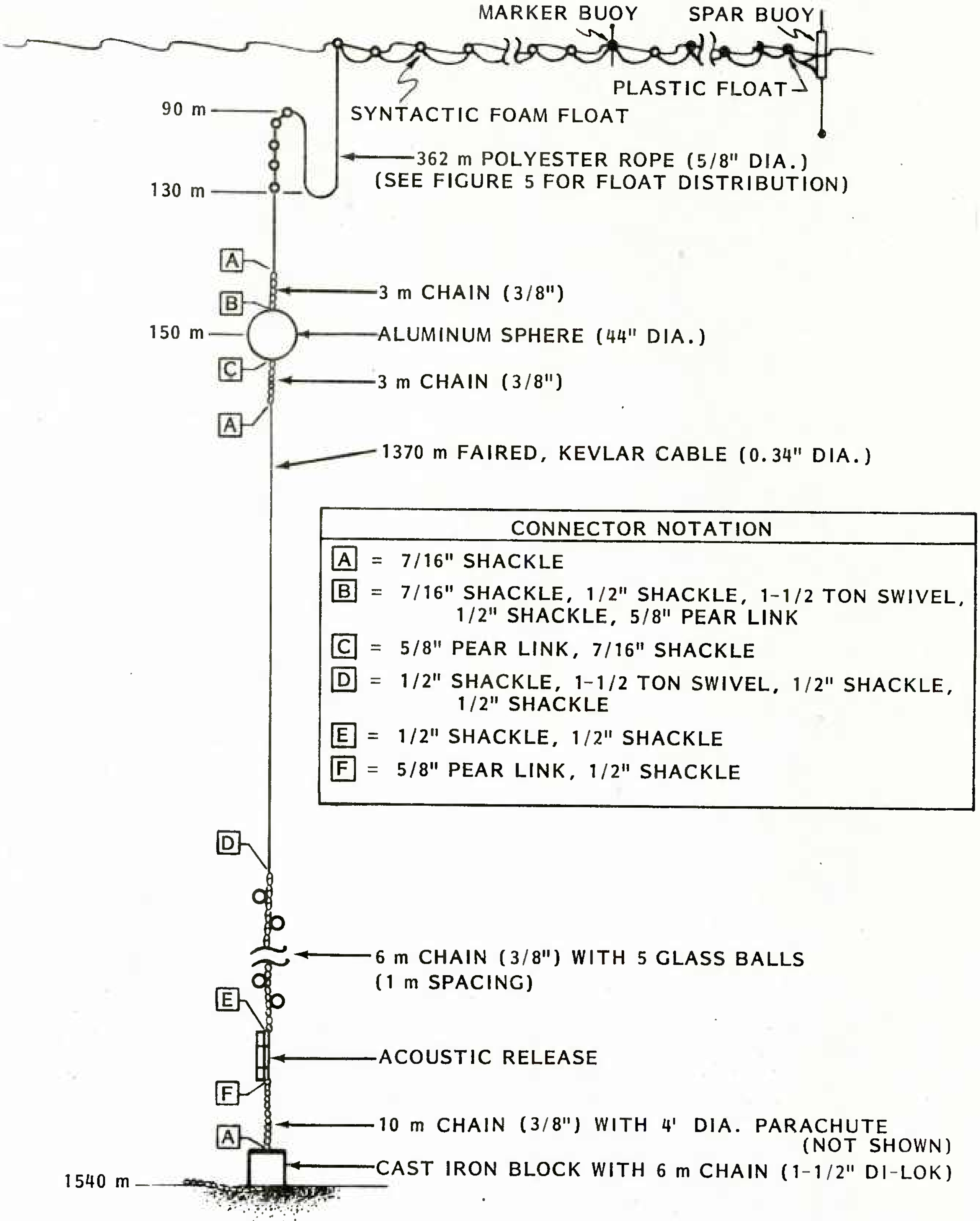


Figure 4. Final mooring design schematic

Figure 5 shows three steady-state moored configurations for the final design. These results were obtained using the computer program developed by Wang (1977) and the design current profiles shown in Figure 6. The design current profiles were constructed from ocean current data garnered from the Environmental Atlas of the Tongue of the Ocean, Bahamas (1967). This data, which is considered to be the best available, is also plotted in Figure 6.

Profile I, shown on the left in Figure 6, is the weakest of three current profiles. It is based on the mean current data found for January, the month in which the buoy system was to be deployed. Hence it was used in the analysis to compute the most expected mooring response. Because of the meager amount of data, it was difficult to construct a single current profile that would adequately represent a worst case for purposes of analysis. Consequently, Profiles II and III were constructed. A comparison of the two can be seen on the right in Figure 6.

Based on the analyses preformed, the salient features of the Figure 4 design include:

- A minimum back-up recovery capability of 480 N (108 lb).
- A system safety factor of 5 while moored in Profile III.
- Deployment descent speed of 1.2 m/s and a deployment safety factor of 6.
- Anchor sized to hold in current Profile III.

The amount of back-up recovery is to insure recovery of the mooring parts remaining after a break occurs. In the absence of currents, the system will take on the equilibrium shape shown in Figure 4 and have a system safety factor

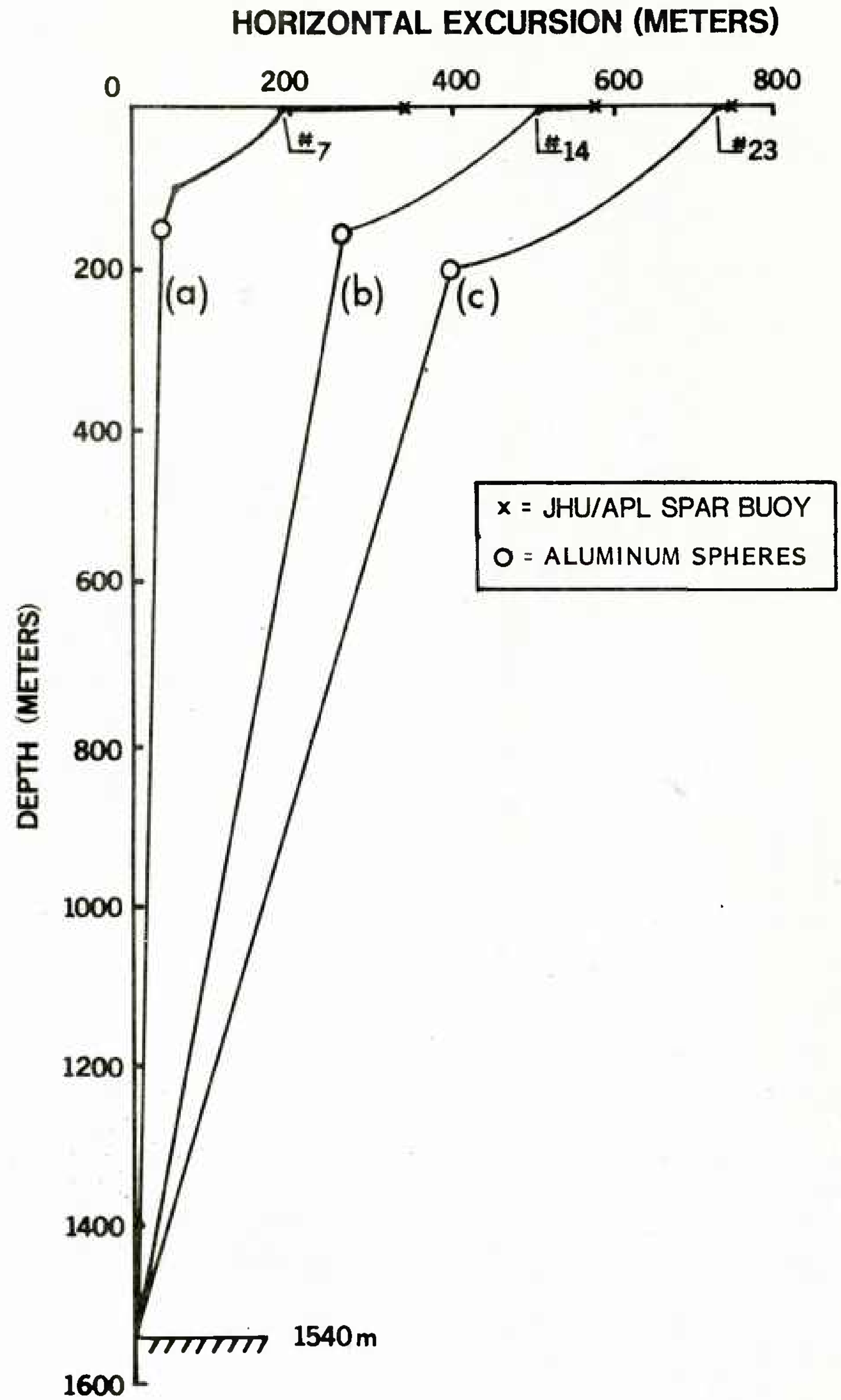


Figure 5. Mooring configurations as a function of design current profile: (a) Profile I, (b) Profile II, (c) Profile III. Current profiles are given in Figure 6. Note also that the numbers shown identify a particular surface float which is attached to the tetherline as indicated in Figure 7.

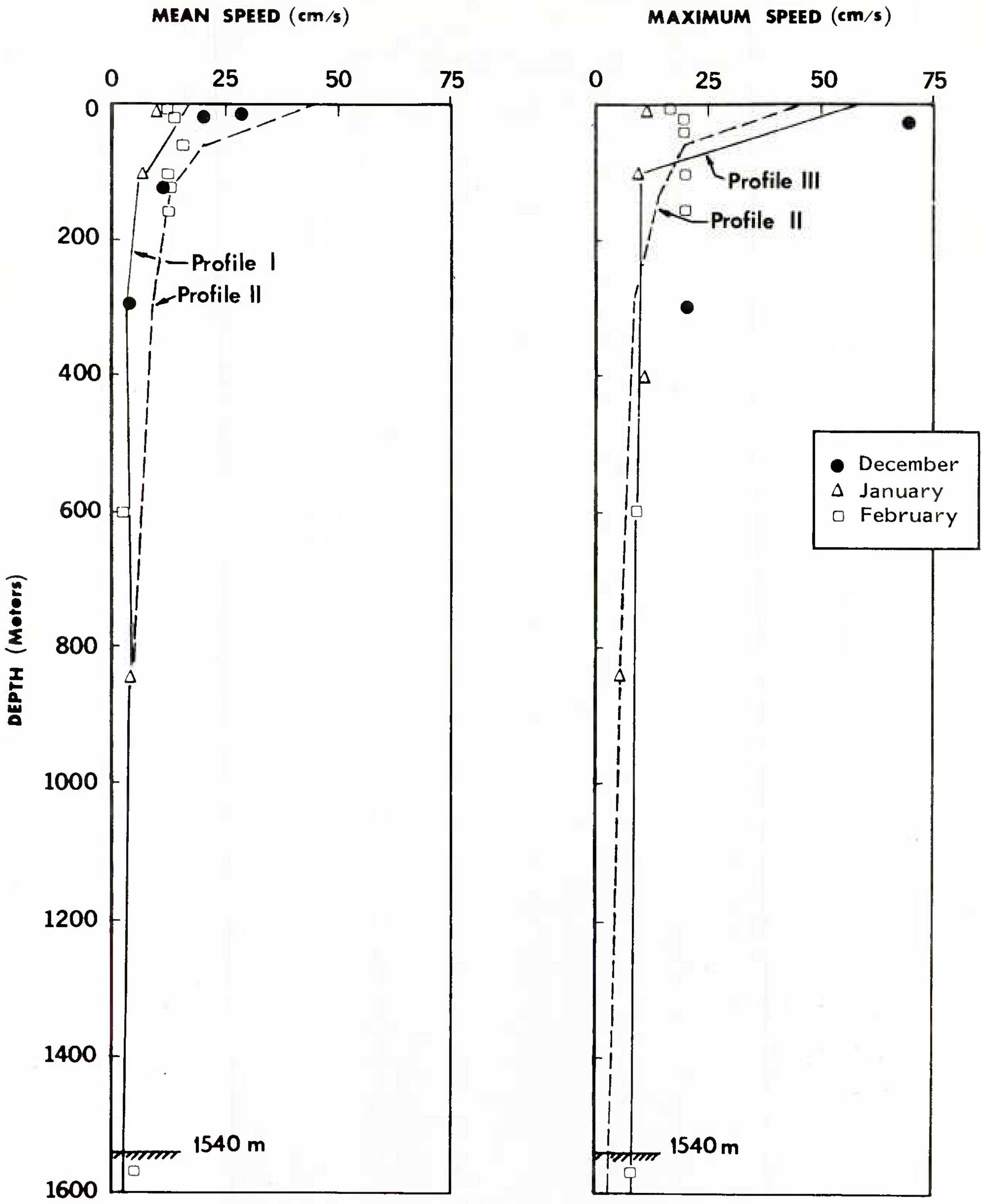


Figure 6. Ocean current data and design current profiles.

of 7 1/4. As current is applied, cable tensions increase and, therefore, system safety factor decreases. The effect of current on mooring configuration can be seen in Figure 5.

B. Final Design: A Description

Four types of flotation are used to meet the system buoyancy requirements. As shown in Figure 4, these include: a 1.12 m (44 in.) diameter, aluminum sphere, five glass balls, and a number of syntactic foam and inflatable, plastic floats. The aluminum sphere provides 4.9 kN (1100 lb) of net positive buoyancy and, in the absence of currents, is located about 150 m below the surface. When exposed to the design current profiles, Figure 5 shows that it will not exceed its maximum safe working depth of 915 m.

The five glass balls are used to provide the system back-up recovery capability. They are contained in plastic "hard hats", and conveniently bolted to the 6 m length of chain located just above the acoustic release in Figure 4. To prevent sympathetic implosion, they are spaced about one meter apart. Each glass ball has a 41 cm (16 in.) diameter, 217 N (44.8 lb) of net positive buoyancy, and is rated for a 6100 m water depth.

The syntactic foam and plastic floats are attached to the rope that tethers the JHU/APL spar buoy to the aluminum sphere. Figure 7 gives the distribution of these floats on the tether line at the time of deployment and during the experiment. The five floats located just above the sphere are intended to produce the slack cable configuration shown in Figure 4, and the remaining floats the reserve buoyancy needed in currents.

The syntactic foam floats are football-shaped with a 30.5 cm diameter and a 61 cm length. Each float also has 110 N (25 lb) of net positive

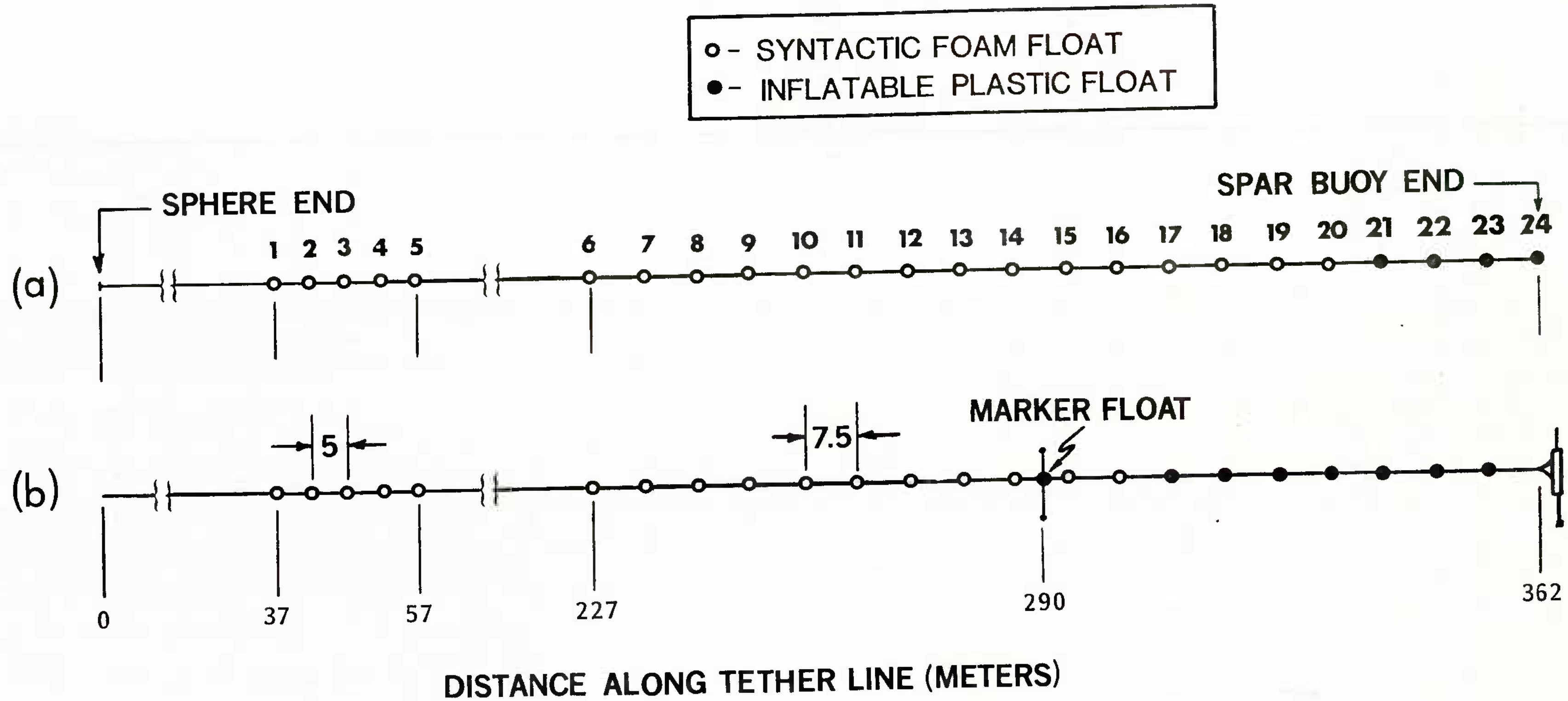


Figure 7. Tether line float distribution: (a) AT deployment, and (b) during experiment. Floats are spaced 5 m apart between 37 m and 57 m, and $7\frac{1}{2}$ m between 22 m and 362 m. An exception, however, is the marker float.

buoyancy, a 1830 m maximum safe working depth, and is attached inline with the tether line. In contrast, a plastic float is tear-drop-shaped with a 28 cm diameter and 120 N (27 lb) of net positive buoyancy. The spar-type buoy shown in Figure 8 was also fabricated using a plastic float. This particular buoy was used to mark the location of tether line on the ocean surface. It was attached to the tether line, at the location shown in Figure 7(b), after the buoy system was deployed.

Two types of synthetic lines are used in the mooring: Kevlar and polyester. The Kevlar cable is used to moor the aluminum sphere to the anchor and is a Miniline construction. The polyester rope is used as the tether line and is a Uniline construction. Both types of construction are registered trade names of Wall Rope Industries, and are essentially torque-free. Kevlar is a registered trade name of E. I. DuPont de Nemours and Company.

The basic components comprising each line are identified in the Figure 9 photographs. The fiber core shown in Figure 9(a) is polyester, constructed in parallel strands and surrounded by a thin layer of neoprene. In contrast, the Kevlar yarns in Figure 9(b) are a braided construction to minimize stretch and twisting under load. Both lines are protected with a tightly braided polyester fiber jacket.

The Kevlar mooring line is an electromechanical cable that was used as a strength member only. It has a 8.6 mm (0.34 in.) diameter, 38 kN breaking strength, a 1370 m unstressed length, and is faired (as shown in Figure 9(b)) with nylon yarn. The hydrodynamic performance of this relatively new type of fairing is given in a report by Milburn and Rispin (1981). The Kevlar cable is terminated with eye-splices around galvanized thimbles, and the polyester rope with Kevlar "stoppers." Some characteristics of the polyester rope

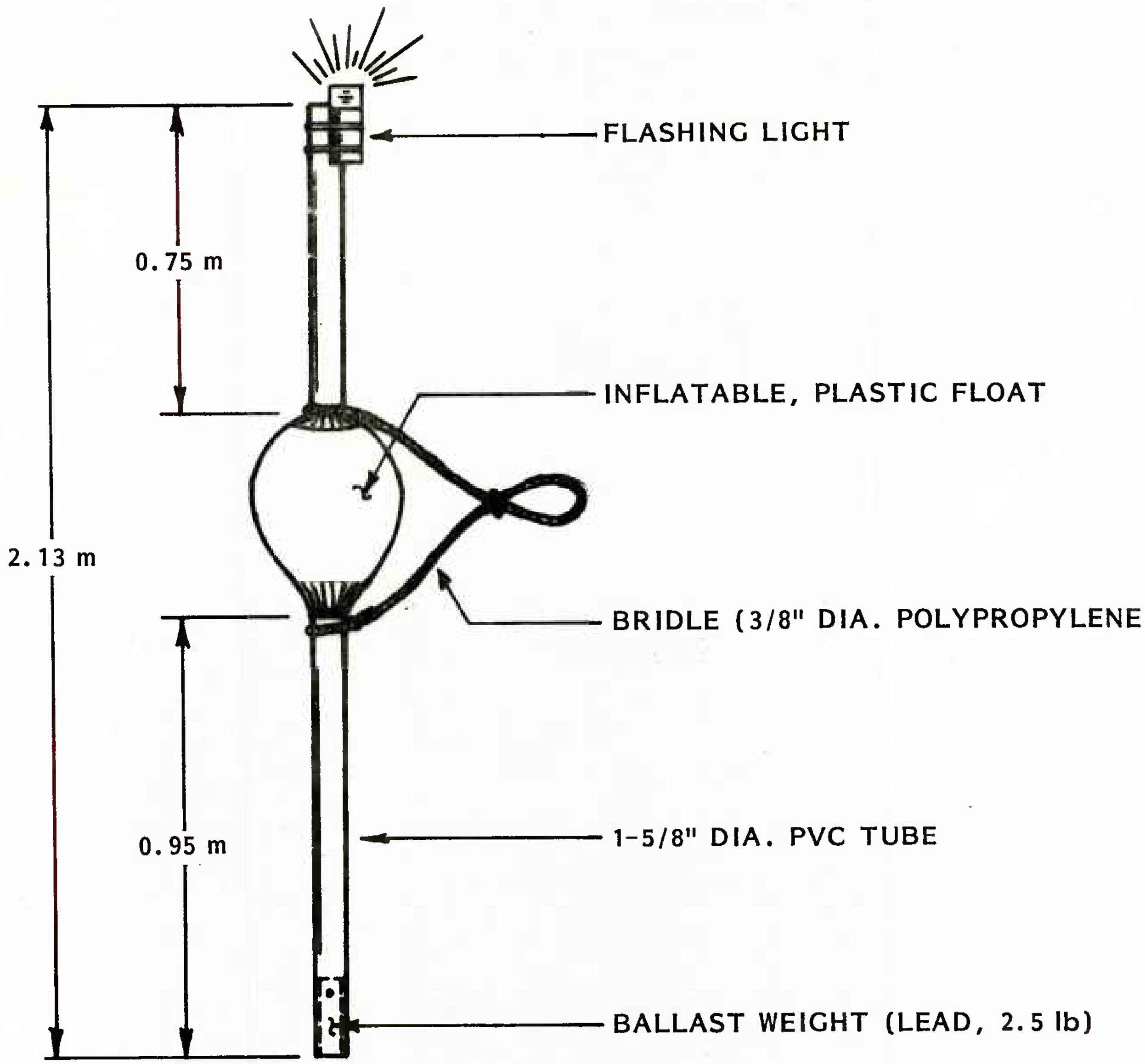
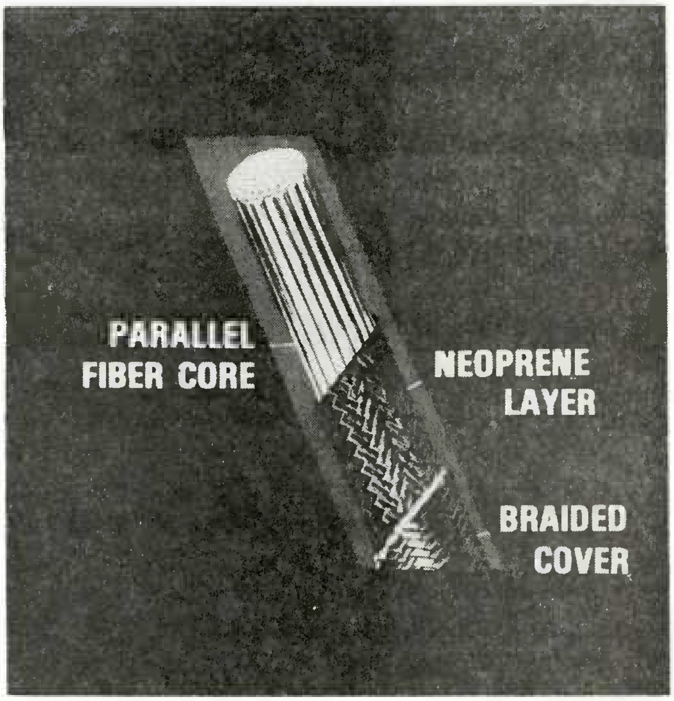
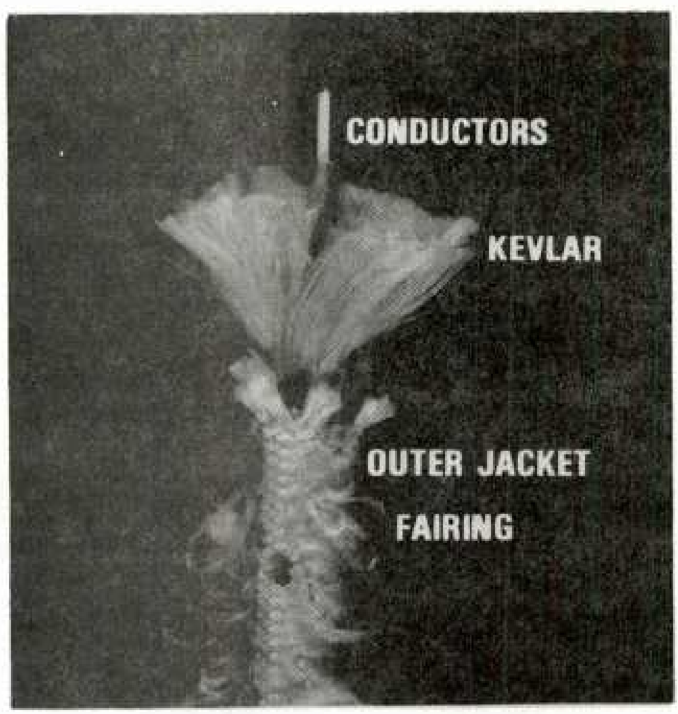


Figure 8. Marker float



(a) Tether line, a polyester rope



(b) Mooring line, a Kevlar cable

Figure 9. Synthetic lines

include: 1.6 cm (5/8 in.) diameter, 71 kN breaking strength, 362 m unstressed length, and no fairing.

The remaining mooring components include: several lengths of 9.5 mm (3/8 in.) mooring chain used for its abrasion resistance; a 1.2 m diameter parachute, attached to the chain just above the anchor, to reduce system descent speed; an acoustic release for system recovery; and, a cast iron block with 6 m of 3.8 cm (1-1/2 in.) Di-Lok chain to maintain the mooring on station. All mooring chain is hot-dipped galvanized, proof coil steel, and the cast iron block weighs about 8 kN in air and 6.9 kN in water. The Di-Lok chain is to provide additional holding power.

III. AT-SEA OPERATION AND OBSERVATIONS

The buoy system was successfully deployed from the R/V COVE, a JHU/APL ship, on January 3, 1982. Prior to deployment, all system components were connected and judiciously arranged on the ship's stern for an anchor-last deployment. The ship was also positioned about 3 km down-weather from the mooring site.

In the anchor-last technique, the tether line was the first component launched from the stern. Figure 7(a) shows the tether line float distribution used at this time. With the ship slowly proceeding to the mooring site, the sphere was the next major component deployed. It was followed by the 1370 m long mooring line, 6 m length of chain with glass balls attached, and the acoustic release. It took about 30 to 40 minutes to deploy all these parts. When the acoustic release was deployed, the ship was still down-weather from the mooring site. Hence the deployed components were slowly towed to the mooring site where the anchor was dropped, completing the mooring deployment.

Because of their weight, the sphere and anchor were launched using an auxiliary lifting line and a quick-release. All other components were deployed by hand.

Weather conditions during deployment were fairly good. Average wind speeds measured 7 to 9 m/s and average wave height was about one meter.

Shortly after the mooring deployment, the JHU/APL spar buoy was flown by helicopter to the mooring site from Andros Island. Personnel on two rubber boats deployed from the R/V COVE, connected the spar buoy to the tether line. Flotation on the tether line was also redistributed to that shown in Figure 7(b).

After connecting the spar buoy, it was found that only one of the surface floats (number 6 in Figure 7) was totally submerged. This indicates a weak current profile and is in agreement, although fortuitously, with the response predicted for Profile I in Figure 5. It was also observed that the spar buoy had little movement, indicating small dynamic effects from the mooring.

On January 11, 1982, about nine days after their deployment, the spar buoy and mooring were successfully recovered. Based on a preliminary evaluation of the data measured, it appears that mooring motion did not degrade the results.

IV. CONCLUSIONS

The mooring described herein is a simple and relatively inexpensive method for anchoring surface buoys. Based on its use in the Standard Krypton, the mooring was found to be easy to deploy and recover. In a moderate sea state 3 condition it was also found that mooring motion was essentially

decoupled from that of the spar buoy's. Lastly, a comparison of the predicted and actual amounts of tether line found on the surface indicates that Profile I in Figure 6 represents a reasonable operational design current profile for the Tongue of the Ocean in January.

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